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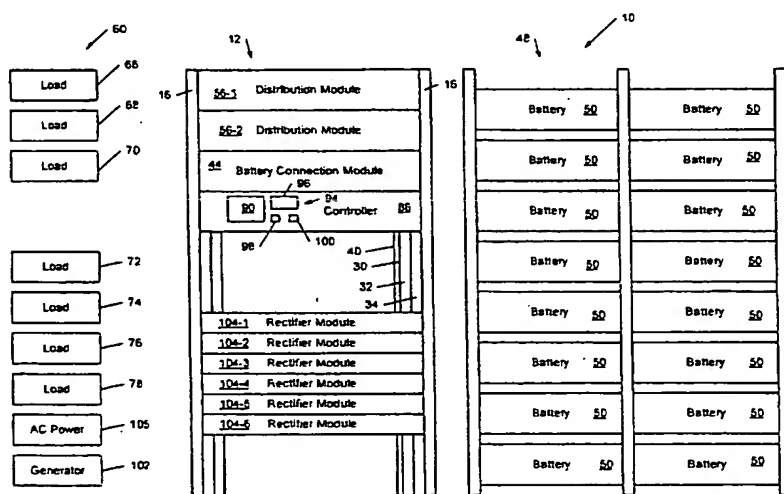
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(54) Title: BACKUP BATTERY RECHARGE CONTROLLER AND BATTERY RECONNECT SYSTEM FOR A TELECOMMUNICATIONS POWER SYSTEM



(57) Abstract: A telecommunications power system according to the invention includes a power bus and a battery module with a plurality of batteries that are connected to the power bus. A distribution module is connected to the power bus. A plurality of loads is connected by the distribution module to the power bus. A plurality of rectifier modules is connected to the power bus and usually at least one AC power source. A generator may provide backup AC power to the rectifier modules when the AC power source is interrupted. A controller is connected to the rectifier modules and the generator and may disconnect the batteries using the contactor when a voltage of the batteries falls below a low voltage disconnect threshold when AC power is lost and/or the rectifier modules fail. The controller

minimizes current surge and high voltage transients when the rectifier modules begin providing power and the contactor closes to reconnect the batteries to the power bus. To minimize current surge and high voltage transients, the controller lowers a voltage of the rectifier modules to the voltage of the batteries before the contactor reconnects the batteries to the power bus. After reconnection, the controller gradually increases the voltage of the rectifier modules to the float voltage. The controller employs a serial communications protocol over a communications bus. A controller includes a battery recharging control module that allows the user to select a first mode of operation that allows the generator to recharge the battery when the generator provides the backup AC power. A second mode of operation prevents the batteries from recharging when the generator provides the backup AC power. A third mode of operation decreases current provided by the generator to charge the batteries when the generator is in an overload state until the overload state ends. A fourth mode of operation prevents battery charging when the generator is in the overload state.

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BACKUP BATTERY RECHARGE CONTROLLER AND BATTERY RECONNECT SYSTEM FOR A TELECOMMUNICATIONS POWER SYSTEM

5 TECHNICAL FIELD OF THE INVENTION

This invention relates to telecommunications power systems. More particularly, this invention relates to the recharging of backup batteries in a telecommunications power system that is connected to a generator, and the reconnection of backup batteries to the telecommunications power system after the backup batteries are disconnected to prevent excessive battery discharge.

BACKGROUND AND SUMMARY OF THE INVENTION

Telecommunications power systems generally employ rectifiers that generate a direct current (DC) voltage from an alternating current (AC) power source. Distribution modules include circuit breakers that connect the rectifiers to loads and that distribute current to the loads. The loads in a telecommunications power system typically include telephone switches, cellular equipment, routers and other associated equipment. In the event that AC power is lost, the telecommunications power systems initially rely on backup batteries to provide power and to prevent costly down time. Generators are typically used for longer outages. Telephone switches, cellular equipment and routers normally carry thousands of calls and/or data streams that will be interrupted if power is lost causing a significant loss of revenue.

The backup batteries provide power for a predetermined backup period which varies depending on the number and size of the loads. The number and size of the backup batteries that are required to provide power during the predetermined backup period also varies depending on the number and size of the loads. The backup batteries should provide a sufficient time to allow skilled technicians to reach the site, to troubleshoot and to fix the problem or to connect a backup generator. Some systems use backup batteries until a generator that provides backup AC power is started to temporarily provide power when the AC power source is lost. While AC power is out, the generator provides power for the loads and charges the back up batteries. As a margin of safety, the capacity of the generator is generally 20% larger than the maximum power required to supply the loads and to charge the backup batteries. As can be appreciated, the cost of the generator increases significantly as capacity increases.

In an effort to limit the size of the backup generator to reduce the cost of the telecommunications power system, some operators separate the DC power bus into first and second sections. A contactor provides a connection between the first and second sections of the DC power bus and is normally closed. When AC power is lost, the contactor is opened. A generator that is connected to the first section provides power to the loads but does not charge the backup batteries. When the AC power source returns, the generator shuts down or is placed in a standby mode. The contactor is closed and the system returns to normal operation.

Sometimes, however, the technicians are unable to solve the problem quickly and/or backup generators are not readily available. If the backup batteries continue to provide power beyond the predetermined backup period, the backup batteries discharge excessively which will shorten the useful life of the backup batteries. Since backup batteries often constitute approximately 50% of the cost of the telecommunications power system, operators often disconnect the backup batteries and accept the loss of service to prevent damage to the backup batteries.

During normal operation, the rectifiers operate at a float voltage of the backup batteries. When the rectifiers operate at the float voltage, the backup batteries provide little or no power and remain in a charged state. When the AC power is lost or the rectifiers fail, the output voltage of the rectifiers decreases below the float voltage and the batteries begin providing power to the loads through the distribution module. As the backup batteries discharge, they reach an output voltage below which damage to the backup batteries generally occurs.

To prevent damage to the backup batteries, operators generally disconnect the batteries in one of two ways. A contactor disconnects either the loads or the backup batteries. Since the contactor is a single point of failure, customers increasingly request battery disconnection rather than load disconnection. When the former method is employed, the telecommunications power system remains operational if the contactor fails during normal operation. When the latter method is employed, service is lost if the contactor fails during normal operation.

Once AC power returns after a failure that results in the backup batteries being disconnected due to excessive discharge, the rectifiers begin providing power to the loads. If the backup batteries are reconnected by closing the contactor, sharp voltage transients and high in-rush current occurs which may damage the batteries and the contactor and disrupt the operation of the loads.

Other systems that employ the split DC power bus with the first and second sections do not use the contactor between the first and second sections. In these systems, the rectifiers that charge the backup batteries are not available for load sharing and temperature stress distribution during normal operation.

5 One example of a telecommunications power system according to the invention includes a power bus and a plurality of batteries that are connected to the power bus. A distribution module is connected to the power bus. A plurality of loads are connected to the distribution module. A plurality of rectifier modules are connected to the power bus and at least one AC power source. A generator
10 provides backup AC power to the rectifier modules when the AC power source is interrupted. A controller is connected to the rectifier modules and the generator. The controller includes a battery recharge control module that allows the user to select a first mode of operation that allows the generator to recharge the backup batteries when the generator provides the backup AC power. A second mode of
15 operation prevents the batteries from recharging when the generator provides the backup AC power. A third mode of operation decreases current provided by the generator to charge the batteries when the generator is in an overload state until the generator is not in the overload state. A fourth mode of operation prevents the batteries from recharging when the generator is in an overload state.

20 The backup battery recharge controller according to the invention allows the telecommunications power system operator to prevent the backup batteries from charging when the generator provides backup AC power. As a result, a smaller generator can be used to provide the backup AC power to the loads when the AC power source is interrupted. Alternately, the telecommunications power system
25 operator can limit the amount of current supplied to the backup batteries when the generator is in an overload state. This mode of operation allows the backup batteries to charge when excess capacity is available from the generator.

30 The battery reconnect system according to the present invention eliminates the problems that may occur when batteries are reconnected in a telecommunications power system. The battery reconnect system senses whether the contactor is open. If the contactor is open and if the rectifier voltage is higher than a reconnect threshold, a reconnect procedure begins. The rectifier voltage is gradually decreased until the rectifier voltage approximately equals the disconnected battery voltage. The battery reconnect system closes the contactor. Subsequently, the reconnect system

gradually increases the voltage of the rectifier to the float voltage while controlling current in a current limiting mode such that the batteries are optimally recharged.

As can be appreciated, the reconnect system according to the invention provides a very reliable solution for reconnecting backup batteries to the telecommunications power system after AC power is lost and the backup batteries are disconnected to prevent low voltage discharge. The need for intervention by a highly skilled technician is eliminated. The reconnect system reduces the cost of operation and increases up time of the telecommunications power system.

BRIEF DESCRIPTION OF THE DRAWINGS

10 The various advantages of the present invention will become apparent to those skilled in the art after reading the following specification and by reference to the drawings in which:

FIG. 1 is a block diagram of a telecommunications power system according to the invention that includes a frame that is connected to a plurality of loads and a battery pallet with a plurality of batteries;

FIG. 2 is a functional block diagram of the telecommunications power system of FIG. 1;

FIG. 3 is a functional block diagram of the distribution module of FIG. 1 in further detail;

20 FIG. 4 is a functional block diagram of the rectifier module of FIG. 1 in further detail;

FIG. 5 is a functional block diagram of the battery connection module of FIG. 1 in further detail;

FIG. 6 illustrates the display associated with the controller; and

25 FIG. 7 is a flow chart illustrating steps for controlling battery recharge according to the invention.

FIG. 8 is a block diagram of a telecommunications power system that includes a frame that is connected to a plurality of loads and a battery pallet with a plurality of batteries according to the invention;

30 FIG. 9 is a functional block diagram of the telecommunications power system of FIG. 8;

FIG. 10 is a simplified circuit that illustrates rectifiers that are connected to an AC source, loads, a contactor, and a battery;

35 FIG. 11 is a functional block diagram of the distribution module of FIG. 8 in further detail;

FIG. 12 is a functional block diagram of the rectifier module of FIG. 8 in further detail;

FIG. 13 is a functional block diagram of the battery connection module of FIG. 8 in further detail;

5 FIG. 14 is a flow chart illustrating steps for reconnecting the backup batteries after AC power is lost and the backup batteries are disconnected to prevent excessive battery discharge;

FIG. 15A illustrates an output voltage of a rectifier when AC voltage is restored after the backup batteries are disconnected;

10 FIG. 15B illustrates the rectifier voltage exceeding a reconnect voltage threshold which initiates the reconnect procedure;

FIG. 15C illustrates the rectifier voltage gradually decreasing to the battery voltage according to the reconnect procedure;

15 FIG. 15D illustrates the rectifier voltage equal to the battery voltage when the contactor is closed according to the reconnect procedure; and

FIG. 15E illustrates the rectifier voltage and battery voltage gradually increasing while current is provided by the rectifiers to the batteries.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 The preferred embodiments herein described are not intended to be exhaustive or to limit the invention to the precise form disclosed. This description is limited to the preferred embodiment only and is intended to describe the invention to enable one of ordinary skill in the art to practice the invention.

Referring now to FIG. 1, a telecommunications power system 10 is illustrated and includes one or more frames 12 that include a rack 16. A direct current (DC) bus 30 includes first and second conductors 32 and 34 that extend
25 along the rack 16 in a vertical direction and that are separated by an insulating layer (not shown). A communications bus 40 is located adjacent to the DC bus 30 and likewise includes a layer (not shown) that insulates the communications bus 40 from the first and second conductors 32 and 34.

30 The design of the telecommunications power system 10 is modular such that the capacity of the system 10 can be changed by adding or removing modules from the system 10. The design of the telecommunications power system 10 has been optimized through the use of modular connectors (not shown) to facilitate the connection and disconnection of the modules from the frame 12.

The telecommunications power system 10 includes one or more battery connection modules 44 that are connected to the DC bus 30 and the communications bus 40. The battery connection module 44 is connected to a pallet of backup batteries 48 that includes a plurality of battery cells 50. In a preferred embodiment, each of the battery cells provides a two volt output and a relatively high current output. The battery cells 50 are typically connected into battery strings that contain from 24 to 26 battery cells. Each battery string provides 48 VDC for telephone switch and router applications. Depending upon the length of time desired for the battery backup and the size of load to be supplied, the number and/or capacity of the backup batteries may be varied. Skilled artisans can appreciate that other voltages, string sizes and packaging arrangements can be employed for telecommunications power systems having other power requirements.

One or more distribution modules 56 are connected to the DC bus 30 and the communications bus 40. The distribution modules 56 distribute power to one or more loads 60 such as telecommunications switches, cellular equipment and routers. For example in FIG. 1, the distribution module 56-1 delivers power to loads 66, 68 and 70. The distribution module 56-2 delivers power to loads 72, 74, 76, and 78. The number of distribution modules depends on the size and number of the loads that are associated with the telecommunications power system 10.

A master controller 86 is connected to the DC power bus 30 and to the communications bus 40. The master controller 86 includes a display 90 and an input device 94 which preferably includes a touch pad 96 and buttons 98 and 100. An alternate display can be a computer monitor. The input device 94 and the display 90 can be combined in a touch screen display. A keyboard and/or a mouse may also be employed. The master controller 86 preferably provides an internet browser-like interface that is navigated using the touch pad 96 in a conventional point-and-click manner or using the touch pad 96 and the buttons 98 and 100. Alternately, text-based and/or menu-driven interfaces can be provided.

The telecommunications power system 10 further includes one or more rectifier modules 104 that are connected to the DC bus 30 and the communications bus 40. A generator 102 is connected to the same point as the AC power source 105 that supplies the rectifier modules 104. The AC power source 105 is connected to the rectifier modules using circuit breakers 107. The generator 102 provides backup AC power when required in a conventional manner. In addition, the generator 102 provides a first control signal to the controller 86 or the

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communications bus 40 that identifies when the generator 102 is on. The generator 102 provides a second control signal when the generator 102 is in an overload state. The generator 102 may only provide a "generator on" signal or a "generator overload" signal or both signals. The generator 102 can be dedicated to the telecommunications power system 10 or be added to the telecommunications power system 10 on an as-needed basis. Connections between the loads, the generator, and the backup batteries have been omitted in FIG. 1 for purposes of clarity.

Using the input device 94, the telecommunications system operator defines the operation of the system 10 when the generator 102 is provided. When the telecommunications system operator selects a first operational mode, the system 10 operates normally. The generator 102 powers the loads and charges the batteries if needed when the AC power source is lost. When the telecommunications operator selects a second operational mode, the controller 86 prevents the backup batteries from charging when the generator is on. When the telecommunications operator selects a third operational mode, the controller 86 decreases current that is available for charging the backup batteries if the generator is in an overload state current is limited until the generator is no longer in the overload state and remains at this limit until AC power returns. When the telecommunications operator selects a fourth operational mode, the controller 86 prevents the backup batteries from changing when the generator is in the overload state until the AC power returns.

Referring now to FIG. 2, the telecommunications power system of FIG. 1 is illustrated in further detail. In use, one or more AC power sources 105 provide voltage that is typically between 80 and 300 VAC at a frequency between 45 and 65 Hz. The rectifier modules 104 rectify the AC voltage provided by the AC sources 105. The rectifier modules 104 provide a controllable output voltage and current and are rated at 48 volts nominal and 50 or 200 amps. Skilled artisans can appreciate that other rectifier voltage and current outputs can be provided depending upon the requirements of the telecommunications power system.

Depending upon the type of backup batteries employed, the output voltage of the rectifier modules 104 will be set higher than 48 volts. Typically, the rectifier modules 104 operate at a float voltage of the backup batteries during normal operation so that the backup batteries do not discharge current. The backup batteries are typically connected in battery strings 106 containing 24 to 26 battery

cells. The float voltage is typically set between 52 and 54 VDC depending upon the characteristics of the backup batteries.

The rectifier modules 104 preferably include a shunt, sensing leads, and an analog to digital (A/D) converter for sensing rectifier voltage and current. The
5 rectifier module 104 transmits digital signals representing the rectifier voltage and current (in addition to other digital control and communications signals) to the controller 86 via the communication's bus 40. Likewise, the battery control modules 44 and the distribution modules 56 include a shunt, sensing leads, and an analog-to-digital converter for sensing battery and load voltages and currents. Preferably,
10 the controller 86 employs a serial communications protocol that is insensitive to noise. In a preferred embodiment, the communications system employs serial communications using a CAN protocol such as CAN version 2.0B.

The distribution modules 56 include one or more circuit breakers (not shown) which are preferably modular plug-in type circuit breakers to facilitate
15 connection and disconnection of the loads 60. The distribution module 56 connects the loads 60 to the DC power bus 30.

The signal output of the generator 102 can be connected by an input/output (I/O) interface (not shown) to the communications bus 40. The I/O interface ensures that the "generator on" signal and the "generator overload" signal comply
20 with the CAN protocol. Alternately, the signal outputs of the generator 102 can be connected directly to one or more logical inputs of the controller 86 or to one or more neurons that are associated with the modules.

Referring now to FIG. 3, the distribution module 56 is illustrated in further detail. The distribution module 56 includes one or more circuit breakers (not
25 shown) that are located between the loads 60 and the DC bus 30. The distribution module 56 includes a contactor 150, a shunt 154, an A/D converter 158, an I/O interface 162, and a neuron 166. The contactor 150 is controlled by the neuron 166 through the I/O interface 162. The contactor 150 connects and disconnects the loads 60 and is provided if the telecommunications system operator desires load
30 disconnection. Because contactors are a single point of failure, some system operators opt for battery disconnection instead of load disconnection. When the contactor 150 fails, power to the loads is interrupted. When battery disconnection is used, the load is not interrupted when a battery disconnect contactor (see FIG. 5) fails. Both types of disconnection may be employed if desired.

The neuron 166 is preferably a controller that includes a processor and memory (not shown). The neuron 166 performs local processing for the distribution module 56 and I/O communications between the distribution module 56, the master controller 86, and other modules in the telecommunications power system 10. The I/O module 162 is connected to the neuron 166 and to the A/D converter 158. The A/D converter 158 includes sensing leads 170 and 172 that sense a voltage across the contactor 150. The sensing lead 170 and sensing lead 174 sense a voltage across the shunt 154 so that a load current can be calculated. The sensing leads 174 and 176 sense a voltage output across the loads 60.

Referring now to FIG. 4, the rectifier modules 104 are illustrated in further detail and include a rectifier 180, a shunt 182, an A/D converter 184, an I/O interface 186, and a neuron 188. The neuron 188 performs local processing functions for the rectifier module 104 and controls I/O communications between the rectifier module 104, the master controller 86 and other modules in the telecommunications power system 10. The A/D converter 184 includes sensing leads 190, 192, and 194. The A/D converter 184 senses a rectifier voltage using the sensing leads 192 and 194 and a rectifier current by sensing a voltage across the shunt 182 using leads 190 and 192.

Referring now to FIG. 5, the battery connection module 44 is illustrated and includes a neuron 200, an I/O interface 202, an A/D converter 204, a shunt 206 and a contactor 208. The neuron 200 performs local processing functions and I/O communications between the battery connection module 44, the master controller 86 and other modules in the telecommunications power system 10. The contactor 208 is controlled by the neuron 200 through the I/O interface 202. The A/D converter 204 includes sensing leads 210, 212, 214, and 216. The A/D converter 204 senses a battery voltage using the leads 214 and 216. The A/D converter 204 senses a battery current by sensing a voltage drop across the shunt 206 using the leads 212 and 214. The A/D converter 204 senses a voltage across the contactor 208 using the leads 210 and 212.

Referring now to FIG. 6, the display 90 that is associated with the master controller 86 is shown. In addition to other screens, the display 90 provides an interface screen 280 for setting the first, second, third and fourth operational modes for the telecommunications power system 10 when the telecommunications power system 10 is connected to the generator 102. The interface screen 280 preferably includes first, second, third and fourth check boxes 282, 284, 286 and 288. The

check box 282 allows the operator to select the first operational mode which allows the backup batteries to be charged when the generator 102 is connected to the telecommunications power system 10. The check box 282 can be omitted if desired and the first operational mode can be set as a default mode.

- 5 The check box 284 allows the operator to select the second operational mode which prevents the backup batteries from charging when the generator 102 is on. The check box 286 allows the operator to select the third operational mode which decreases the current for charging the backup batteries when the generator 102 is in an overload operational state. The current provided to the batteries is
10 reduced until the generator is no longer in the overload operational state. The check box 288 allows the operator to select the fourth mode which prevents battery charging when the generator 102 is in an overload operational state. The check boxes 282, 284, 286, and 288 are preferably mutually exclusive. If one of the check boxes 282, 284, 286, and 288 is selected, the others are deselected. Skilled
15 artisans can appreciate that a text-based interface, a menu-driven interface, and/or switches can be used instead of the check boxes.

Referring now to FIG. 7, the steps for controlling battery recharge when the generator 102 is connected to the telecommunications power system 10 is illustrated. Control begins at step 300. At step 302, control determines if the
20 generator 102 is connected to the telecommunications power system 10. If not, control loops back to step 302. Otherwise, control continues with step 304 where control determines whether the operator selected the second operational mode (to prevent charging of the backup batteries when the generator 102 is on). If the operator selected the second operational mode, control continues with step 306
25 where control determines whether the generator 102 is on. If not, control loops to step 302. Otherwise, control continues with step 308 where control determines whether the current output to the backup batteries equals zero. If it does, control loops to step 302. Otherwise, control continues with step 312 where control reduces the charging current. Then, control loops to step 308.

- 30 Control continues with step 316 (from step 304 when the operator does not select the second operational mode) where control determines if the operator selected the third operational mode (to decrease charging of the backup batteries when the generator 102 is in an overload operational state until the generator is not in the overload state). Control determines whether the generator 102 is in the
35 overload operational state as determined at step 320. If not, control continues with

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step 328. Otherwise, control reduces the current supplied to the backup batteries in step 324 and continues with step 320.

If the third mode is not selected as determined in step 316, control continues with step 328 where control determines if the fourth mode is selected. If not, control
5 continues with step 302. Otherwise, control determines whether the generator 102 is in the overload operational state at step 330. If not, control returns to step 302. Otherwise control determines whether the charging current of the batteries is zero in step 334. If not, control reduces battery charging current in step 338 and returns to step 334.

10 While the backup battery charging current is set to zero when the second and fourth operational modes are selected, the actual current will be slightly greater than zero to prevent battery discharge. The amount of current flow will also depend on the accuracy of current measurement in the telecommunications power system
10.

15 To control charging to the backup batteries, the current output of the rectifier modules 104 is measured and added together. A current limit of the rectifier modules is adjusted to set the proper rectifier current level. For example, with three rectifier modules and a load current of 100A, the current limit of the rectifier modules is set to 33A plus an additional slight amount of current to ensure that the
20 batteries do not discharge. The slight amount of additional current will depend on current regulation and system measuring tolerances. Alternately, the voltage output of the rectifier modules is set slightly above the output voltage of the backup batteries. When AC power returns, a transfer switch that is associated with the generator places the generator in a standby mode for a predetermined period in
25 case the AC power is lost or shuts the generator down.

Referring now to FIG. 8, a telecommunications power system 1010 is illustrated and includes one or more frames 1012, each including a rack 1016. A direct current (DC) bus 1030 includes first and second conductors 1032 and 1034 that
30 *extend along the rack 1016 in a vertical direction and that are separated by an* insulating layer (not shown). A communications bus 1040 is located adjacent to the DC bus 1030 and likewise includes a layer (not shown) that insulates the communications bus 1040 from the first and second conductors 1032 and 1034.

The design of the telecommunications power system 1010 is modular such that the capacity of the telecommunications power system 1010 can be changed by
35 adding or removing modules from the telecommunications power system 1010. The

design of the telecommunications power system 1010 has been optimized through the use of modular connectors (not shown) to facilitate the connection and disconnection of the modules from the frame 1012.

5 The telecommunications power system 1010 includes one or more battery connection modules 1044 that are connected to the DC bus 1030 and the communications bus 1040. The battery connection module 1044 is connected to a pallet of backup batteries 1048 that includes a plurality of battery cells 1050. In a preferred embodiment, each of the battery cells provides a two-volt output and a relatively high current output. The battery cells 1050 are typically connected into
10 battery strings that contain from 1024 to 1026 battery cells. Each battery string provides 1048 VDC for telephone switch and router applications. Depending upon the length of time desired for the battery backup and the size of load to be supplied, the size and/or number of batteries may be varied. Skilled artisans can appreciate that other voltages, string sizes and packaging arrangements can be employed if desired.

15 One or more distribution modules 1056 are connected to the DC bus 1030 and the communications bus 1040. The distribution modules 1056 distribute power to one or more loads 1060 such as telecommunications switches, cellular equipment and routers. For example in FIG. 8, the distribution module 1056-1 delivers power to loads 1066, 1068 and 1070. The distribution module 1056-2 delivers power to loads 1072,
20 1074, 1076, 1078. The number of distribution modules depends on the size and number of the loads that are associated with the telecommunications power system 1010. Connections between the loads and the backup batteries have been omitted for purposes of clarity.

25 A master controller 1086 is connected to the DC power bus 1030 and to the communications bus 1040. The master controller 1086 includes a display 1090 and an input device 1094 that preferably includes a touch pad 1096 and buttons 1098 and 1100. The alternative display can be a computer monitor. The input device 1094 and the display 1090 can be combined in a touch screen display. A keyboard and/or a mouse may also be employed. The master controller 1086 preferably provides an
30 internet browser-like interface that is navigated using the touchpad 1096 in a conventional point-and-click manner or using the touchpad 1096 and the buttons 1098 and 1100. Alternately, a text-based, menu-driven interface can be employed.

Referring now to FIG. 9, the telecommunications power system 1010 further includes one or more rectifier modules 1104 that are connected to the DC bus 1030
35 and the communications bus 1040. The rectifier modules 1104 are connected to an

AC power source 1105 such as that provided by utilities or other power generating systems. Preferably, circuit breakers 1107 are provided between the AC source 1105 and the rectifier modules 1104. Alternately, an AC power bus may be employed.

In use, the AC power provided to the telecommunications power system 1010
5 has a voltage that is typically between 80 and 300 VAC at a frequency between 45 and 65 Hz. The rectifier modules 1104 rectify the AC voltage. The rectifier modules 1104 provide a controllable output voltage and current and are rated at 48 volts nominal and 50 or 200 amps. Skilled artisans can appreciate that other voltages and currents may be provided by the rectifier modules 1104 for systems having different
10 current and voltage requirements.

Depending upon the type of backup batteries employed, the output voltage of the rectifier modules 1104 will be set higher than 48 volts. Typically, the rectifier modules 1104 operate at a float voltage of the backup batteries during normal operation so that the backup batteries do not discharge current. The float voltage is
15 typically between 52 and 54 VDC depending on the battery construction details. The backup batteries are connected as battery strings 1106. The rectifier modules 1104 preferably include a shunt and an analog to digital (A/D) converter for sensing rectifier voltage and current. The rectifier module 1104 transmits digital signals representing the rectifier voltage and current (in addition to other digital control and communications
20 signals) to the controller 1086 via the communications bus 1040. Preferably, the controller 1086 employs a serial communications protocol that is insensitive to noise. In a preferred embodiment, the communications system employs serial communications using a CAN protocol such as CAN version 2.0B.

The distribution modules 1056 include one or more circuit breakers (not
25 shown) which are preferably modular plug-in type circuit breakers to facilitate connection and disconnection of the loads 1060. The distribution module connects the loads 1060 to the power bus 1030.

Referring now to FIG. 10, the operation of the battery reconnect system according to the invention is illustrated by an equivalent circuit that is identified at
30 1120. During use, the AC power source 1122 generates an AC voltage that is input (through circuit breakers that are not shown) to the rectifiers 1124. The rectifiers 1124 generate a DC voltage from the AC voltage. The loads 1128 are connected in parallel to the rectifiers 1124. During normal operation, the voltage output of the rectifiers 1124 is preferably at the float voltage of backup batteries 1132 to prevent current
35 discharge. A battery contactor 1136 connects and disconnects the backup batteries

1132 and is generally closed during operation. When the AC source 1122 is interrupted, the output current of the rectifiers decreases to zero. The backup batteries 1132 begin discharging and provide power to the loads 1128.

To prevent damage to the backup batteries 1132, the battery reconnect system according to the invention disconnects the battery contactor 1136 when the voltage provided by the backup batteries 1132 falls below a low voltage disconnect threshold to prevent damage to the batteries due to excessive discharge. If no other power source is present, the telecommunications power system 1010 is in a failure mode - no power is supplied to the loads 1128 and service is lost.

When the AC source 1122 is re-established, the rectifiers 1124 begin increasing output voltage and current provided to the loads 1128. The battery contactor 1136 remains in an open state. When the rectifiers 1124 reach a reconnection threshold voltage, the reconnect procedure begins. The reconnect procedure decreases the voltage of the rectifiers 1124 until the rectifier output voltage equals the backup battery output voltage. Then, the battery reconnect system closes the battery contactor 1136.

Since the voltage mismatch between the DC output voltage of rectifiers 1124 and the output voltage of the backup batteries is minimized, the battery reconnect procedure reduces or eliminates high transient voltages and in-rush currents that would otherwise occur. The battery reconnect system controls the current in a current limit mode to optimize charging of the backup batteries 1132 without damaging the backup batteries. After closing the battery contactor 1136, the rectifier voltage is gradually increased. The battery reconnection system completes the reconnection procedure when the backup batteries are charged and the rectifier voltage again reaches the float voltage of the backup batteries.

Referring now to FIG. 11, the distribution module 1056 is illustrated in further detail. The distribution module 1056 includes one or more circuit breakers (not shown) that are located between the loads 1060 and the DC bus 1030. The distribution module 1056 includes a contactor 1150, a shunt 1154, an A/D converter 1158, an input/output (I/O) interface 1162, and a neuron 1166. The contactor 1150 is controlled by the neuron 1166 through the I/O interface 1162. The contactor 1150 connects and disconnects the loads 1060 and is provided if the telecommunications system operator desires load disconnection. Because contactors are a single point of failure, some system operators opt for battery disconnection instead of load disconnection. When the contactor 1150 fails, power to the loads is interrupted. When battery disconnection

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is used, the load is not interrupted when the contactor fails. Both types of disconnection may be employed if desired.

The neuron 1166 is preferably a controller that includes a processor and memory (not shown). The neuron 1166 performs local processing for the distribution module 1056 and I/O communications between the distribution module 1056, the master controller 1086, and other modules in the telecommunications power system 1010. The I/O module 1162 is connected to the neuron 1156 and to the A/D converter 1158. The A/D converter 1158 includes sensing leads 1170 and 1172 that sense a voltage across the contactor 1150. The sensing lead 1170 and sensing lead 1174 sense a voltage across the shunt 1154. The sensing leads 1174 and 1176 sense a voltage across the loads 1060.

Referring now to FIG. 12, the rectifier modules 1104 are illustrated in further detail and include a rectifier 1180, a shunt 1182, an A/D converter 1184, an I/O interface 1186, and a neuron 1188. The neuron 1188 performs local processing functions for the rectifier module 1104 and controls I/O communications between the rectifier module 1104, the master controller 1086 and other modules in the telecommunications power system 1010. The A/D converter 1184 includes sensing leads 1190, 1192, and 1194. The A/D converter 1184 senses the rectifier voltage using the sensing leads 1192 and 1194 and the rectifier current by sensing voltage across the shunt 1182 using leads 1190 and 1192.

Referring now to FIG. 13, the battery connection module 1044 is illustrated and includes a neuron 1200, an I/O interface 1202, an A/D converter 1204, a shunt 1206 and a contactor 1208. The neuron 1200 performs local processing functions and I/O communications between the battery connection module 1044, the master controller 1086 and other modules in the telecommunications power system 1010. The contactor 1208 is controlled by the neuron 1200 through the I/O interface 1202. The A/D converter 1204 includes sensing leads 1210, 1212, 1214, and 1216. The A/D converter 1204 senses battery voltage using the leads 1214 and 1216. The A/D converter 1204 senses battery current by sensing a voltage drop across the shunt 1206 using the leads 1212 and 1214. The A/D converter 1204 senses the voltage across the contactor 1208 using the leads 1210 and 1212. The voltages of the battery connection module 1044 and the rectifier modules 1104 can be sensed using the leads 1214 and 1216 and the leads 1192 and 1194, respectively. Alternately, the voltage across the contactor 1208 can be sensed using the leads 1210 and 1212.

When the voltage across the contactor 1208 is approximately zero, the contactor 1208 can be closed.

Referring now to FIGS. 14 and 15A-15E, steps for operating the battery reconnect system are illustrated. Control begins at step 1300. At step 1301, the master controller and/or the neurons determine whether AC power is interrupted and the batteries are discharging. If not, control loops to step 1301. Otherwise, control continues with step 1302 where the master controller 1086 determines if the voltage of the backup batteries is less than a low voltage disconnect threshold. If not, control loops to step 1302. Otherwise, control continues with step 1304 where the master controller and/or the neuron opens the contactor 1208 to disconnect the backup batteries from the telecommunications power system 1010.

Later, the AC source returns, the rectifiers begin to provide power (see Fig. 15A) and the rectifier voltage (V1) increases. In step 1306, the master controller 1086 determines whether the rectifier voltage (V1) is greater than a reconnect voltage threshold (V3) (see Fig. 15B). If not, control loops and continues with step 1306. Otherwise, control continues with step 1308 where the master controller 1086 determines whether the rectifier voltage (V1) equals the battery voltage (V2) within a predetermined tolerance. If not, control continues with step 1310 where control reduces the rectifier voltage (see Fig. 15C) and continues with step 1308. When the rectifier voltage V1 equals the battery voltage V2, the contactor is closed in step 1316 (see FIG. 15D). Control continues with step 1318 where the master controller 1086 determines whether the battery is charged. If not, control continues with step 1320 where control gradually charges the battery by operating in a current limit mode (see Fig. 15E) and allowing rectifier voltage output to gradually increase. Control continues with step 1318 until the backup battery is fully charged. When the battery is charged, control continues with step 1301.

While the preferred embodiment performs control using the master controller 1086, control can be distributed amongst various combinations of neurons, shared by the master controller and one or more neurons, or performed by a neuron.

As can be appreciated from the foregoing, the battery recharge controller according to the present invention eliminates the need for a contactor or a split DC power bus. Since contactors are a single point of failure, the elimination of the contactor improves the reliability of the telecommunications power system. If the contactor fails during use, the batteries will not recharge when AC power returns to the telecommunications power system after a failure. Subsequent loss of AC power may

result in significant loss of service because the batteries will not be charged. In addition, the size of the generator can be tailored more specifically to the application. Since the generator will not necessarily need to supply the backup batteries while supplying the loads, a smaller and lower cost generator can be employed.

- 5 As can also be appreciated, the battery reconnect system prevents high transient voltages and in-rush currents when reconnecting batteries that are disconnected to prevent excessive discharge. The battery reconnect system is automated and does not require skilled technicians to perform manual battery reconnection which reduces owning and operating costs and increases up time. Other
- 10 advantages will be readily apparent to skilled artisans.

- Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the present invention can be implemented in a variety of forms. Therefore, while this invention has been described in connection with particular examples thereof, the true scope of the invention should not be so limited
- 15 since other modifications will become apparent to the skilled practitioner upon a study of the drawings, the specification and the following claims.

CLAIMS

What is Claimed is:

1. A telecommunications power system, comprising:
a power bus;
5 a plurality of batteries that are connected to said power bus;
a distribution module that is connected to said power bus;
a plurality of loads that are connected to said distribution module;
a plurality of rectifier modules that are connected to said power bus
and at least one AC power source;
10 a generator that provides backup AC power to said rectifier modules
when said AC power source is interrupted; and
a controller that is connected to said rectifier modules and said
generator, wherein said controller includes a battery recharging control module that
allows a user to select a first mode of operation that allows said generator to
15 recharge said batteries when said generator provides said backup AC power and a
second mode of operation that prevents said batteries from recharging when said
generator provides said backup AC power.
2. The telecommunications power system of Claim 1 wherein said
controller is a master controller.
- 20 3. The telecommunications power system of Claim 1 wherein said
controller is a neuron that is associated with a module.
4. The telecommunications power system of Claim 1 wherein said
generator provides generator state signals that identify a "generator on" state and a
"generator overload" state.
- 25 5. The telecommunications power system of Claim 4 wherein said
controller allows a user to select a third mode of operation that decreases current
provided by said generator to charge said batteries when said generator is in an
overload state until said overload state ends.
6. The telecommunications power system of Claim 5 wherein said
30 controller allows a user to select a fourth mode of operation that prevents said
batteries from recharging when said generator is in an overload state.
7. A telecommunications power system, comprising:
a power bus;
a plurality of batteries that are connected to said power bus;
35 a distribution module that is connected to said power bus;

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a plurality of loads that are connected to said distribution module;
a plurality of rectifier modules that are connected to said power bus
and at least one AC power source;

a generator that provides backup AC power to said rectifier modules
5 when said AC power source is interrupted; and

a controller that is connected to said rectifier modules and said
generator, wherein said controller includes a battery recharging control module that
allows a user to select a first mode of operation that allows said generator to
recharge said batteries when said generator provides said backup AC power and a
10 second mode of operation that decreases current provided to charge said batteries
when said generator is in an overload state until said overload state ends.

8. The telecommunications power system of Claim 7 wherein said
controller is a master controller.

9. The telecommunications power system of Claim 8 wherein said
15 controller is a neuron that is associated with a module.

10. The telecommunications power system of Claim 7 wherein said
generator provides generator state signals that identify "generator on" and
"generator overload" states.

11. The telecommunications power system of Claim 10 wherein said
20 master controller allows a user to select a third mode of operation that prevents
said batteries from recharging when said generator provides said backup AC
power.

12. The telecommunications power system of Claim 10 wherein said
controller allows a user to select a fourth mode of operation that prevents said
25 batteries from recharging when said generator is said "generator overload" state.

13. A method of operating a telecommunications power system that
includes a power bus, a plurality of batteries that are connected to said power bus,
a distribution module that is connected to said power bus, a plurality of loads that
are connected to said distribution module, a plurality of rectifier modules that are
30 connected to said power bus and at least one AC power source, a generator that
provides backup AC power to said rectifier modules when said AC power source is
interrupted, and a controller that is connected to said rectifier modules and said
generator, comprising the steps of:

providing an operator interface that allows a user to select between
35 first and second modes of operation;

recharging said batteries with said generator when said generator provides said backup AC power and said first mode is selected; and

preventing said generator from recharging said batteries when said generator provides said backup AC power and said second mode is selected.

5 14. The method of Claim 13 further comprising the steps of:
transmitting a generator state signal to said controller that identifies when said generator is on.

 15. The method of Claim 13 further comprising the steps of:
transmitting a generator overload signal to said controller when said
10 generator is in an overload state.

 16. The method of Claim 15 wherein said operator interface allows the user to select a third mode of operation.

 17. The method of Claim 16 further comprising the step of:
decreasing current provided by said generator for charging said
15 batteries when said third mode is selected and said generator is in said overload state until said overload state ends.

 18. The method of Claim 15 wherein said operator interface allows the user to select a fourth mode of operation.

 19. The method of Claim 18 further comprising the steps of:
20 preventing said generator from recharging said batteries when said generator is in said overload state and said fourth mode is selected.

 20. A method of operating a telecommunications power system that includes a power bus, a plurality of batteries that are connected to said power bus, a distribution module that is connected to said power bus, a plurality of loads that
25 are connected to said distribution module, a plurality of rectifier modules that are connected to said power bus and at least one AC power source, a generator that provides backup AC power to said rectifier modules when said AC power source is lost, and a controller that is connected to said rectifier modules and said generator, comprising the steps of:

30 providing an operator interface that allows a user to select between first and second modes of operation;

recharging said batteries with said generator when said generator provides said backup AC power and said first mode is selected; and

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reducing current provided by said generator for charging said batteries when said generator is in an overload state and said second mode is selected until said overload state ends.

21. The method of Claim 20 further comprising the steps of:
5 transmitting a generator state signal to said controller to identify that said generator is on.

22. The method of Claim 21 further comprising the steps of:
transmitting a generator overload signal to said controller to identify
that said generator is in an overload state.

10 23. The method of Claim 20 wherein said operator interface allows a user to select a third mode of operation.

24. The method of Claim 23 further comprising the step of:
preventing said generator from recharging said batteries when said
generator provides said backup AC power and said third mode is selected.

15 25. The method of Claim 22 wherein said operator interface allows a user to select a fourth mode of operation.

26. The method of Claim 25 further comprising the steps of:
preventing said generator from recharging said batteries when said
generator is in said overload state and said fourth mode is selected.

20 27. A telecommunications power system, comprising:
a power bus;
a plurality of batteries that are connected to said power bus;
a distribution module that is connected to said power bus;
a plurality of loads that are connected to said distribution module;
25 a plurality of rectifier modules that are connected to said power bus
and at least one AC power source;

a generator that provides backup AC power to said rectifier modules
when said AC power source is interrupted; and

a controller that is connected to said rectifier modules and said
30 generator, wherein said controller includes a battery recharging control module that
allows a user to select a first mode of operation that allows said generator to
recharge said batteries when said generator provides said backup AC power and a
second mode of operation that prevents said batteries from recharging when said
generator is in an overload state.

35

28. A method of operating a telecommunications power system that includes a power bus, a plurality of batteries that are connected to said power bus, a distribution module that is connected to said power bus, a plurality of loads that are connected to said distribution module, a plurality of rectifier modules that are connected to said power bus and at least one AC power source, a generator that provides backup AC power to said rectifier modules when said AC power source is lost, and a controller that is connected to said rectifier modules and said generator, comprising the steps of:

providing an operator interface that allows a user to select between first and second modes of operation;

recharging said batteries with said generator when said generator provides said backup AC power and said first mode is selected; and

preventing said batteries from recharging when said generator is in an overload state and said second mode is selected.

29. A telecommunications power system comprising:

a battery connection module that is connected to a plurality of batteries; a load;

a rectifier module that is connected to said load, said battery connection module and an alternating current (AC) source;

a contactor that connects said batteries to said load; and

a controller that is connected to said contactor, said battery connection module and said rectifier module, wherein said controller opens said contactor when a voltage of said battery falls below a low voltage disconnect threshold and closes said contactor after said AC source returns while minimizing voltage transients and current surge during reconnection.

30. The telecommunications power system of claim 29 wherein before said contactor is closed, said controller lowers a voltage of said rectifier module to said voltage of said battery connection module.

31. The telecommunications power system of claim 30 wherein after said contactor is closed, said controller gradually increases said voltage of said rectifier module to a float voltage of said batteries as said batteries recharge.

32. The telecommunications power system of claim 31 wherein said loads are connected by a distribution module to a power bus.

33. The telecommunications power system of claim 32 wherein said rectifier module includes a first analog to digital (A/D) converter and a first neuron that generates and transmits a rectifier voltage signal to said controller.

5 34. The telecommunications power system of claim 33 wherein said battery connection module includes a second analog to digital (A/D) converter and a second neuron that generates and transmits a battery voltage signal to said controller.

35. The telecommunications power system of claim 34 wherein said battery connection module senses a contactor voltage across said contactor.

10 36. The telecommunications power system of claim 35 wherein said second neuron transmits a contactor voltage signal based on said contactor voltage to said controller.

37. The telecommunications power system of claim 36 wherein said controller is connected by a communications bus that employs a serial communications protocol to said first and second neurons.

38. The telecommunications power system of claim 37 wherein said communications bus employs a CAN protocol.

39. A method for providing power to a load in a telecommunication system that includes a battery subsystem with a plurality of batteries, a load, a rectifier module connected to said load, and a contactor that connects said batteries to said load, comprising the steps of:

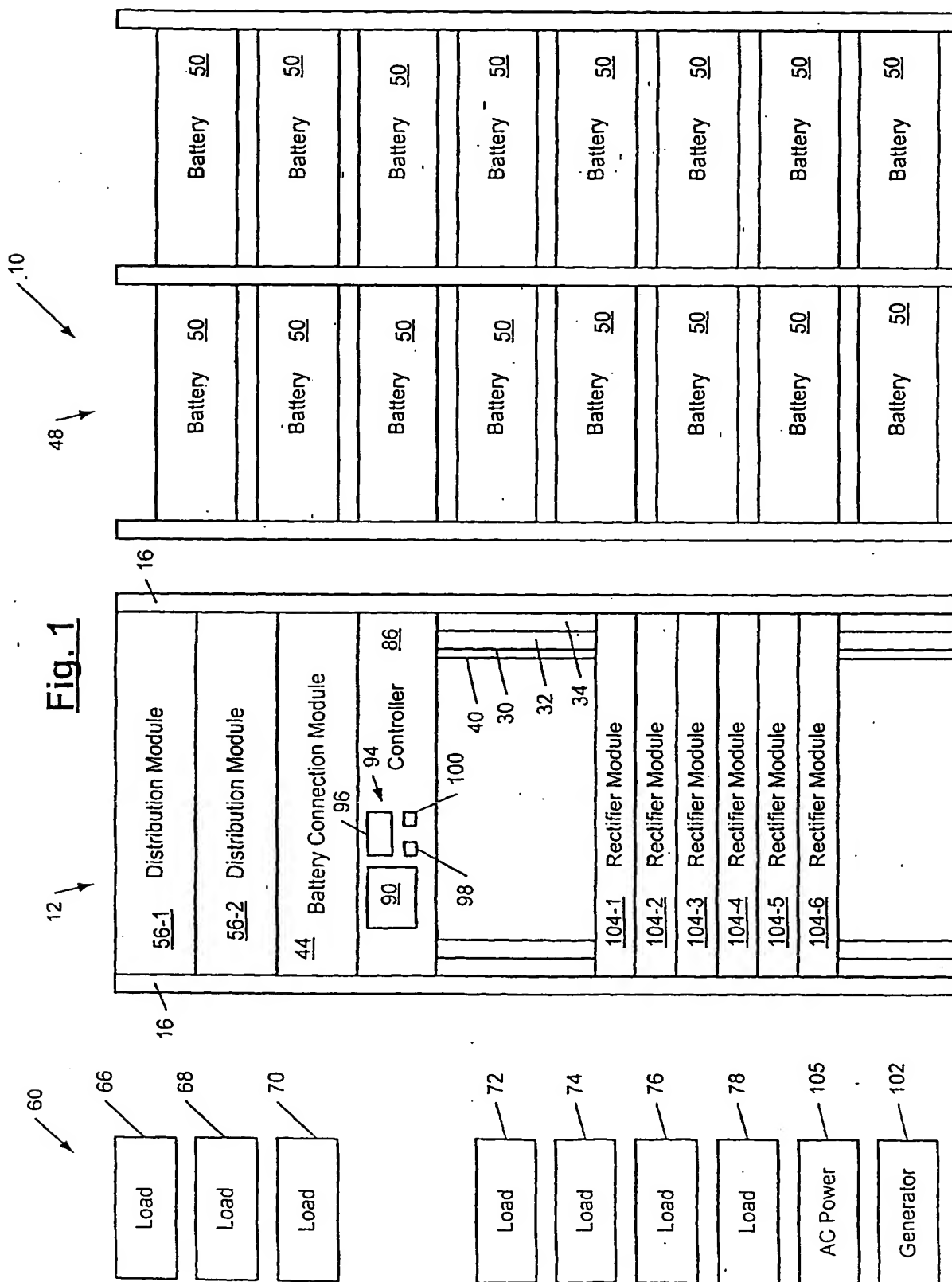
25 monitoring voltage that is output by said batteries with a controller;
disconnecting said batteries from said load using said controller when said voltage output by said batteries falls below a low voltage disconnect threshold; and

minimizing voltage transients and current surge when reconnecting said batteries to said load using said controller.

40. The method of claim 39 further comprising the step of:
gradually lowering a voltage of said rectifier module to said voltage of said batteries before reconnecting said batteries to said load using said controller.

41. The method of claim 40 further comprising the step of:
gradually increasing said voltage of said rectifier module to said float voltage after said batteries are reconnected to said load using said controller.

42. A telecommunications power system comprising:
a power bus;
a battery module;
a contactor that connects said battery module to said power bus;
5 a distribution module that is connected to said power bus;
a plurality of loads connected by said distribution module to said power bus;
a plurality of rectifier modules that are connected to said power bus
and to a plurality of alternating current (AC) power sources; and
a controller that disconnects said battery module using said contactor when
10 a voltage of said battery module falls below a low voltage disconnect when said
rectifier modules fail to provide power, wherein said controller minimizes current
surge and high voltage transients when said rectifier modules begin to provide
power and said controller reconnects said battery module to said load.
43. The telecommunications power system of claim 42 wherein said
15 controller lowers a voltage of said rectifier modules to said voltage of said battery
module before said contactor reconnects the battery module.
44. The telecommunications power system of claim 43 wherein said
controller gradually increases said voltage of said rectifier modules to said float
voltage after said contactor is reconnected to said battery module while charging
20 said battery module.
45. The telecommunications power system of claim 44 wherein said
controller is connected to a communications bus.
46. The telecommunications power system of claim 45 wherein said
rectifier modules include a first analog to digital (A/D) converter and a first neuron
25 that is connected to said communications bus and that generates and transmits a
rectifier voltage signal to said master controller.
47. The telecommunications power system of claim 46 wherein said
battery module includes a second analog to digital (A/D) converter and a second
neuron that is connected to said communications bus and that generates and
30 transmits a battery module voltage signal to said controller.
48. The telecommunications power system of claim 47 wherein said
second A/D converter and said second neuron sense a contactor voltage and
transmit a contactor voltage signal to said controller.



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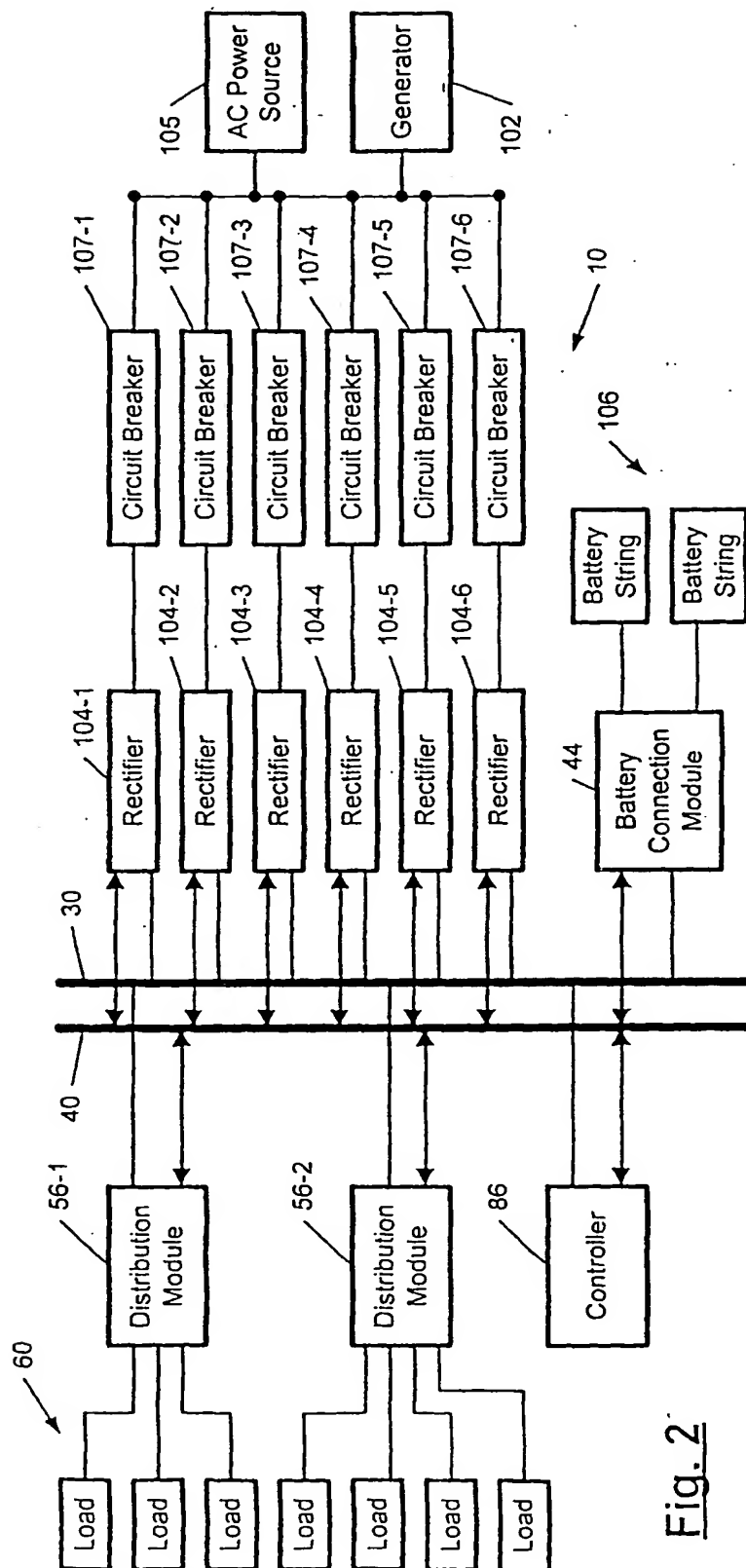


Fig. 2

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Fig. 3

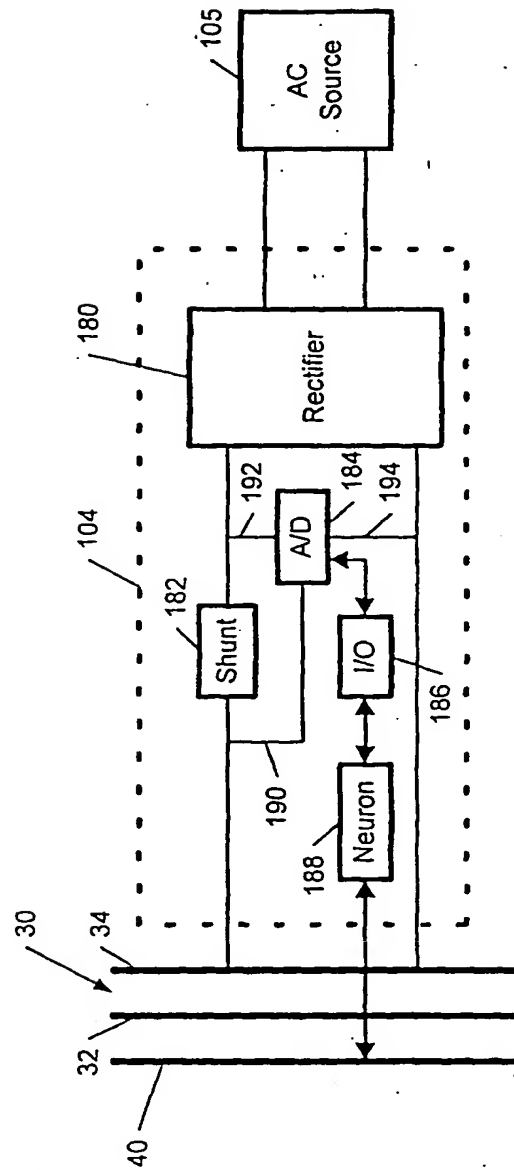
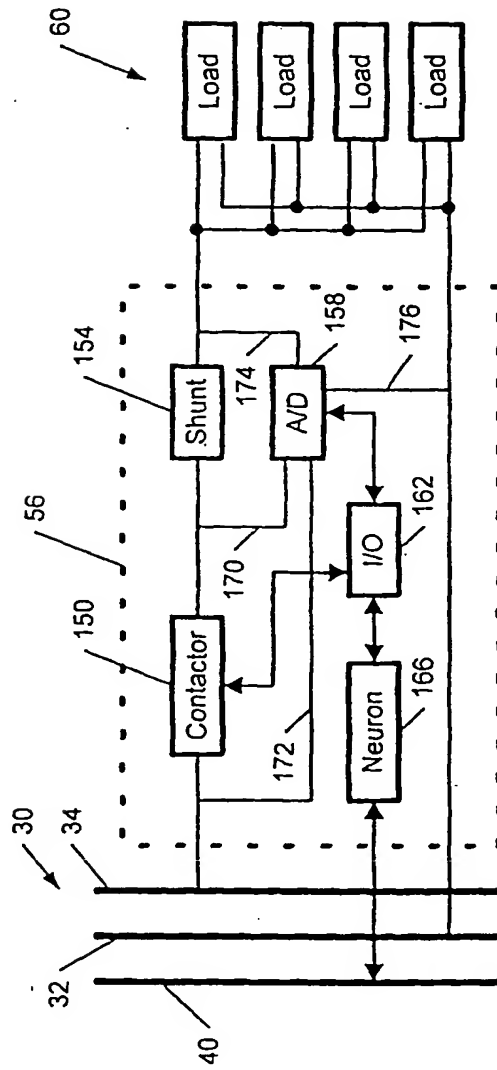


Fig. 4

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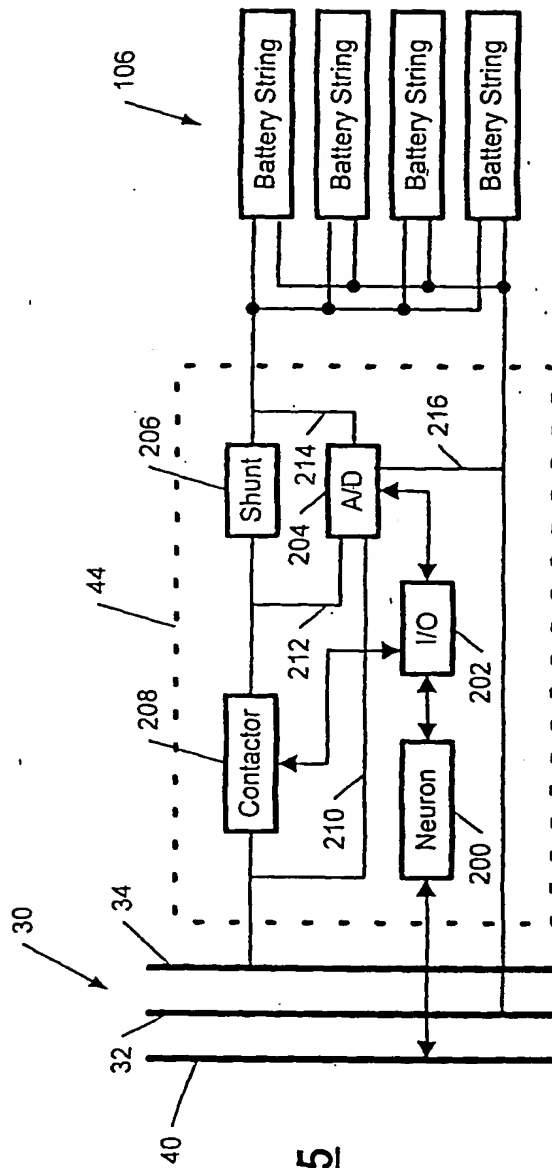


Fig. 5

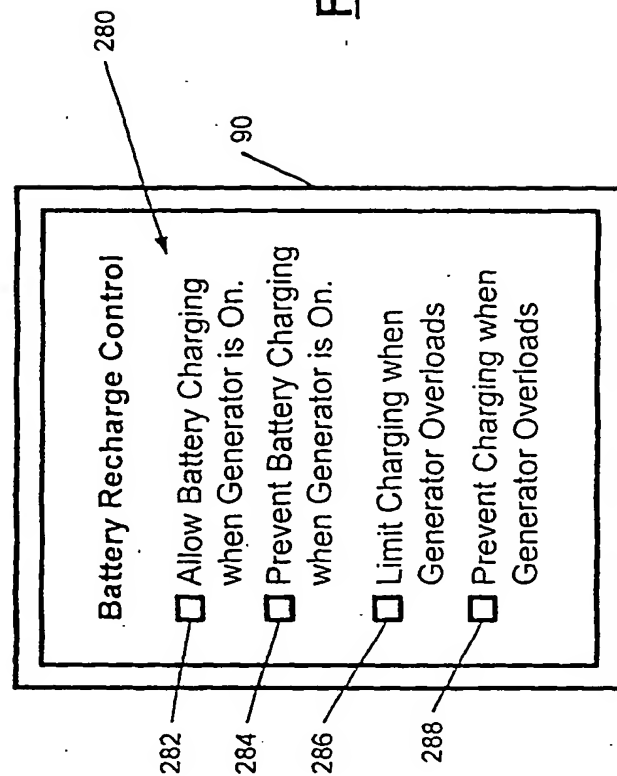
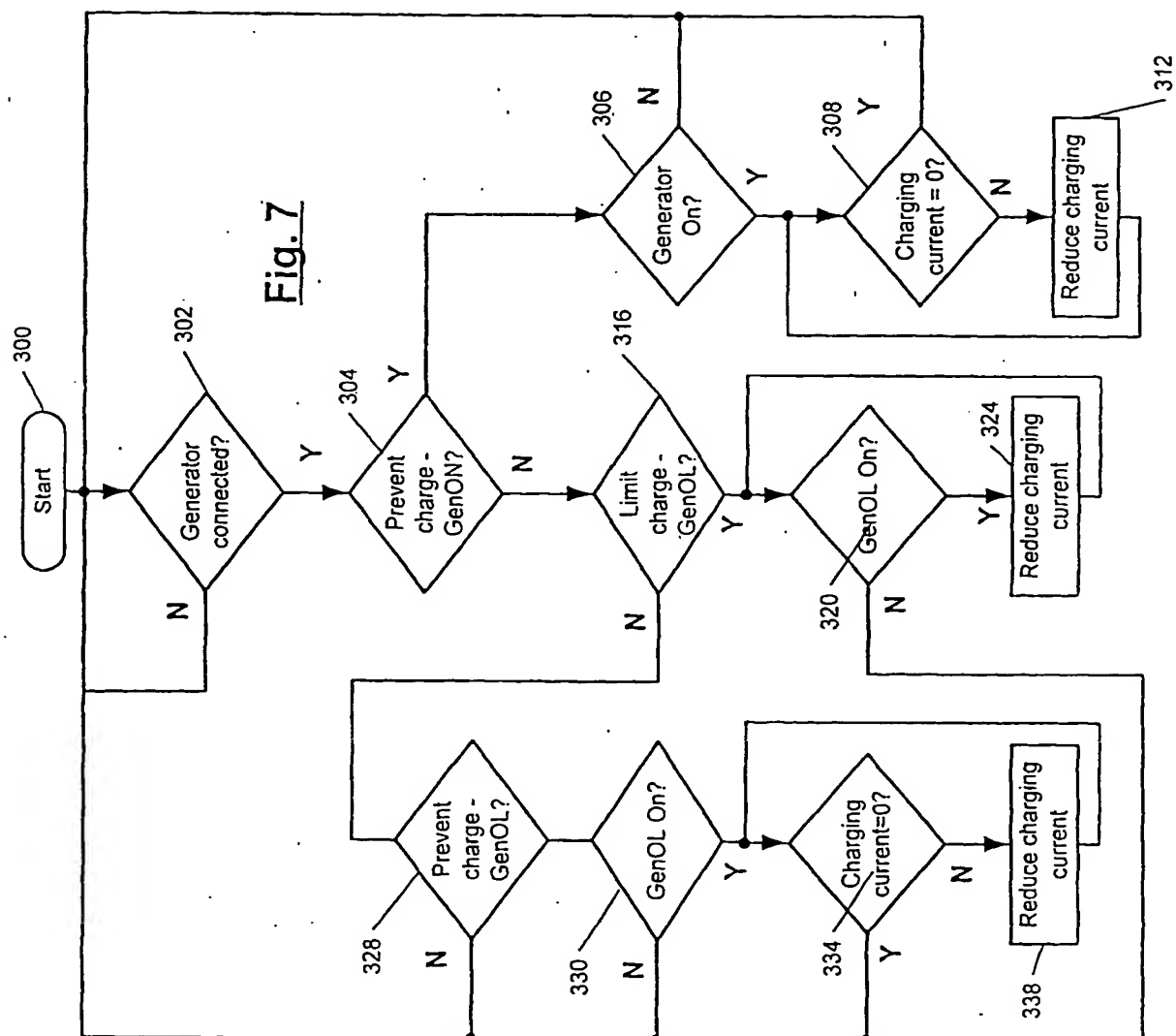
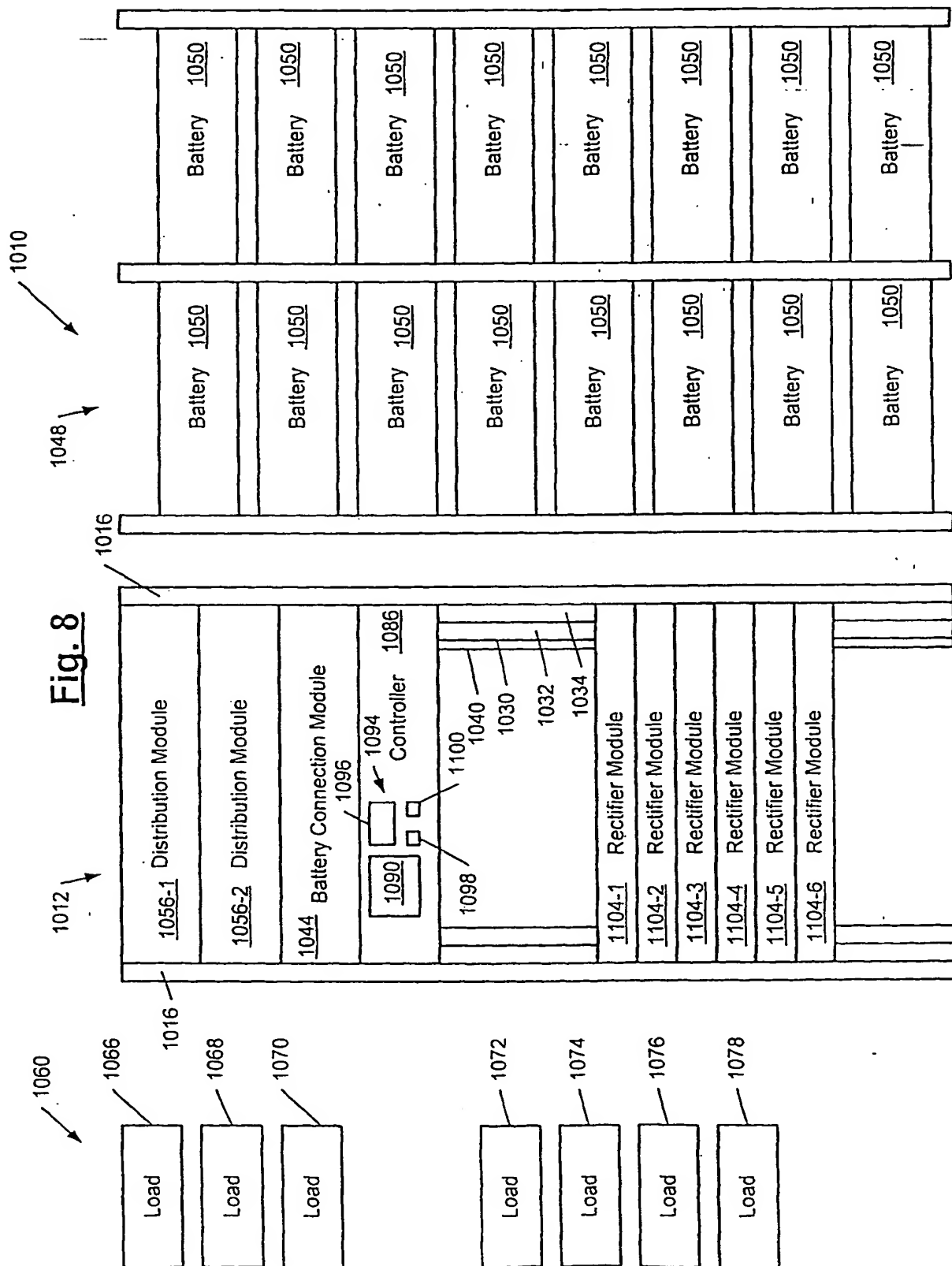


Fig. 6

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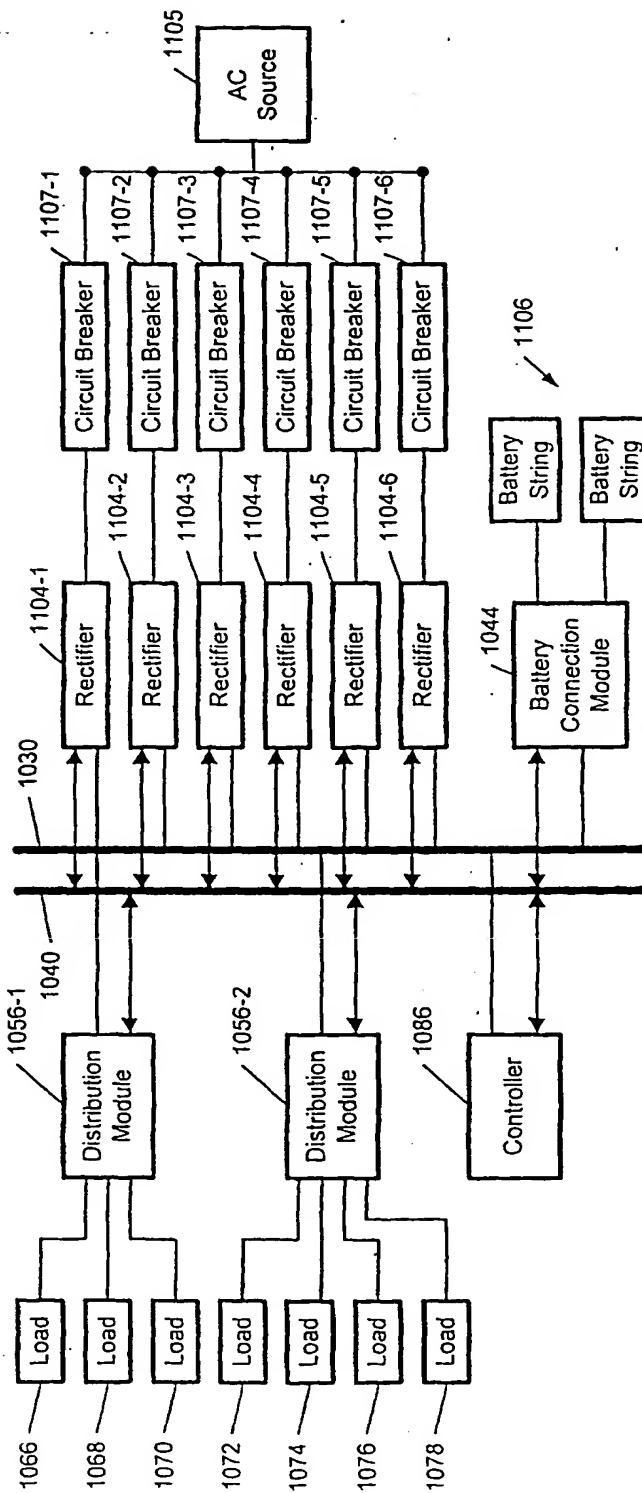


Fig. 9

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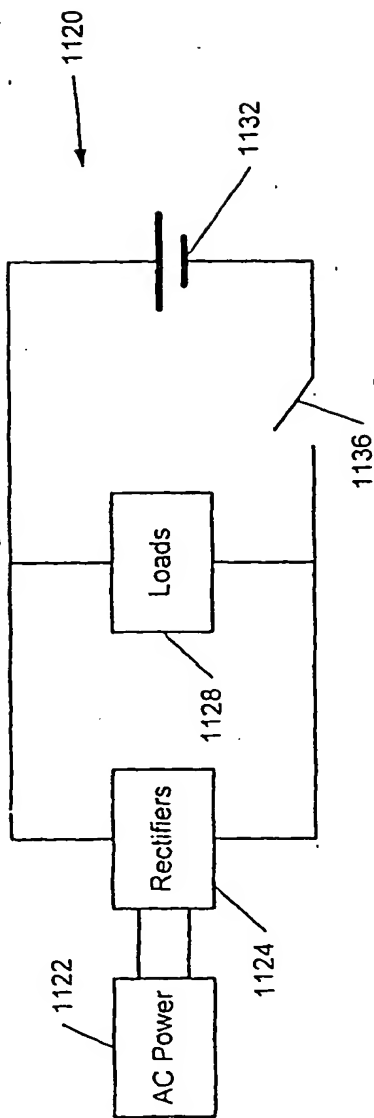


Fig. 10

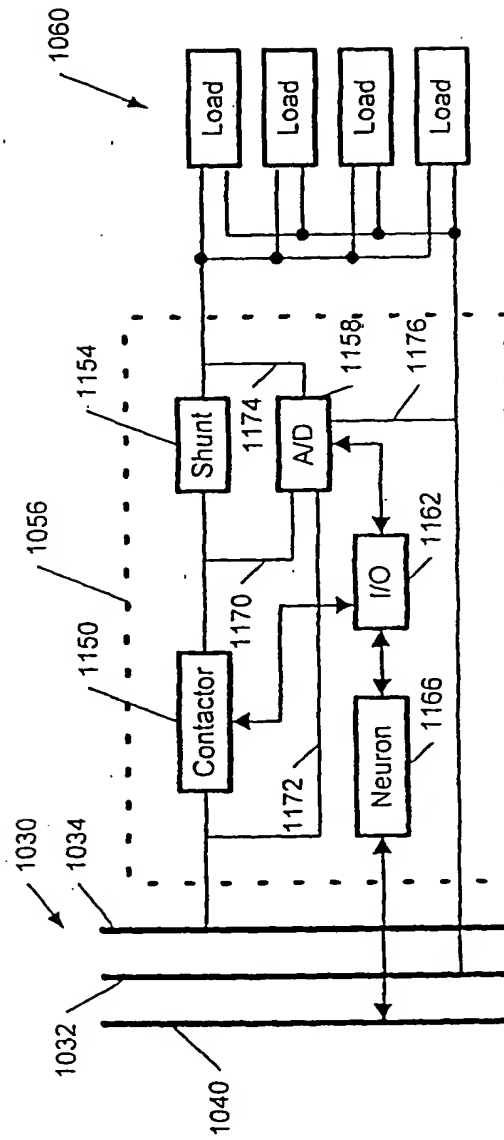


Fig. 11

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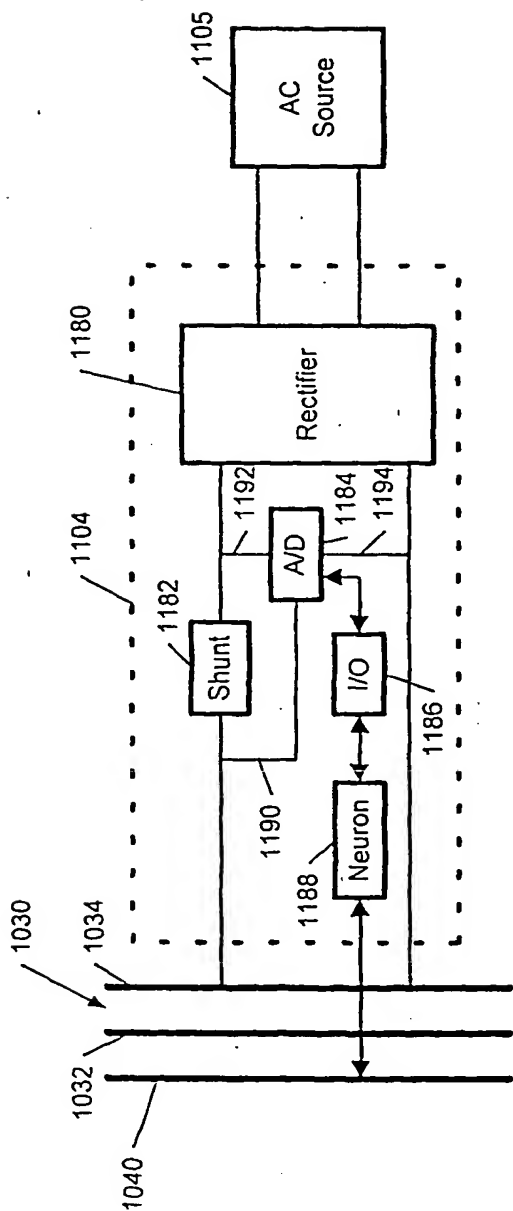


Fig. 12

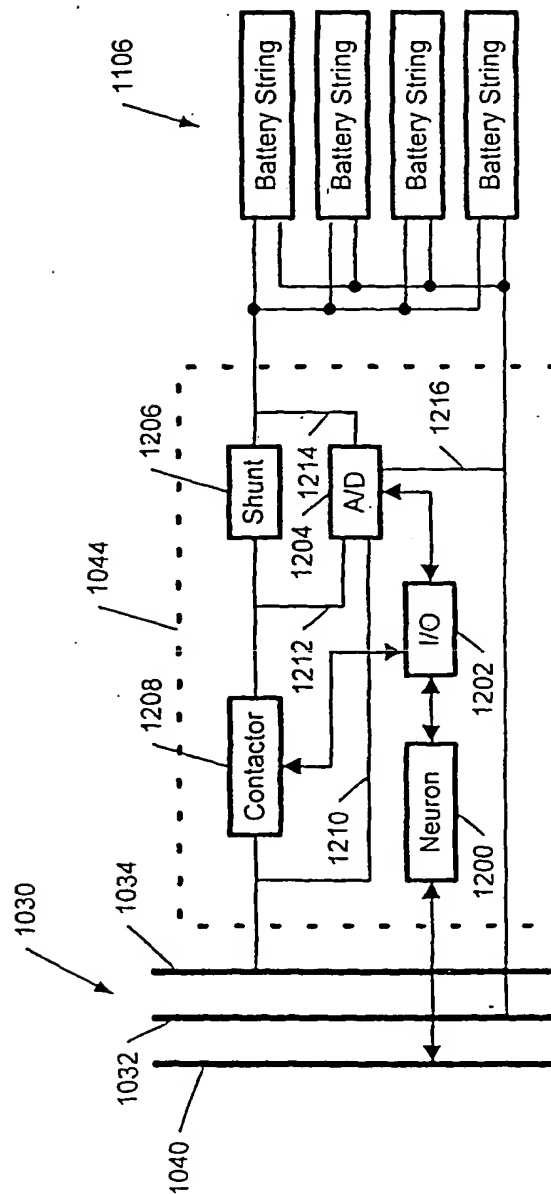
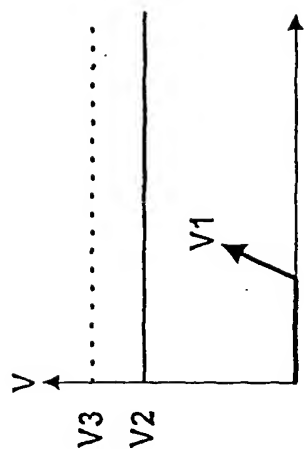
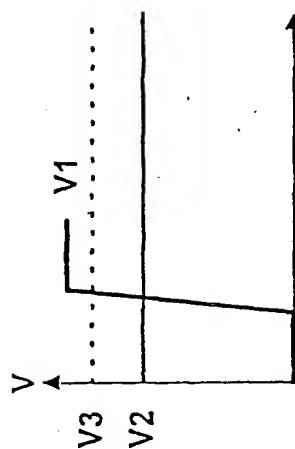
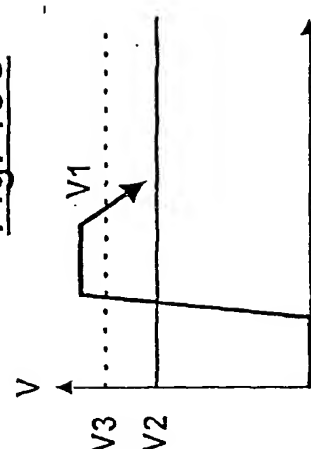
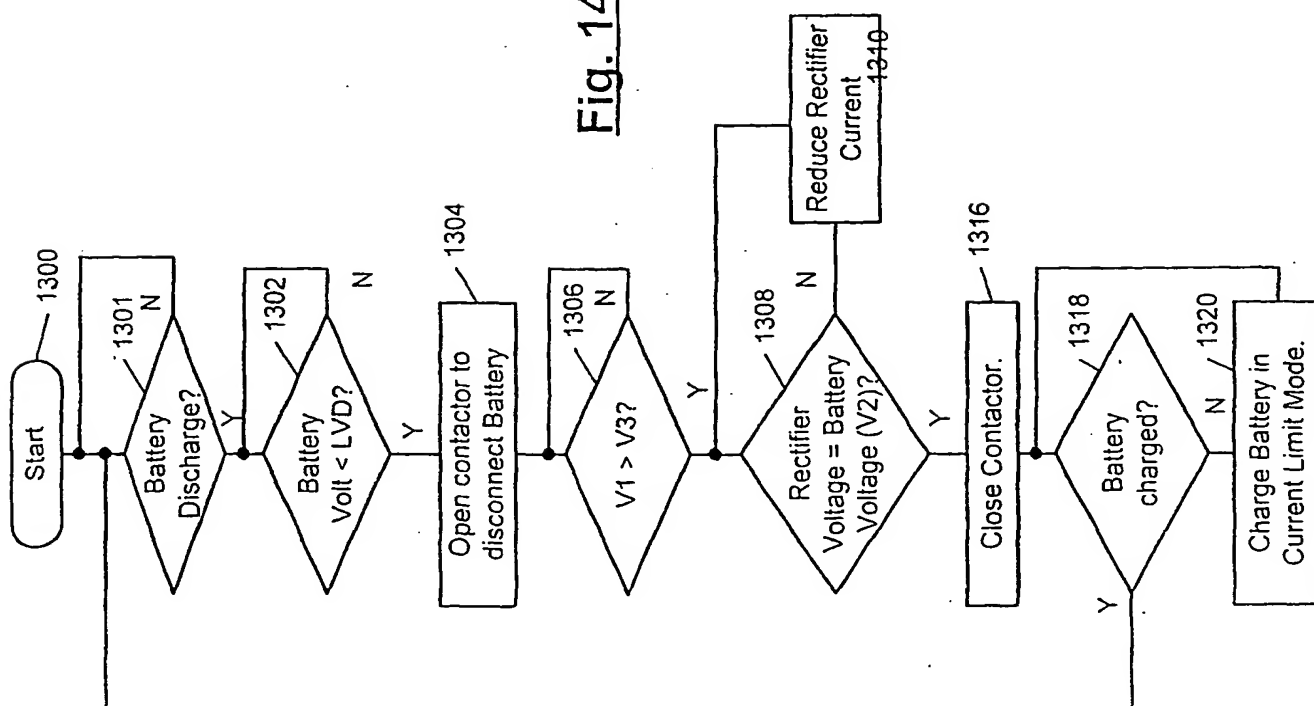
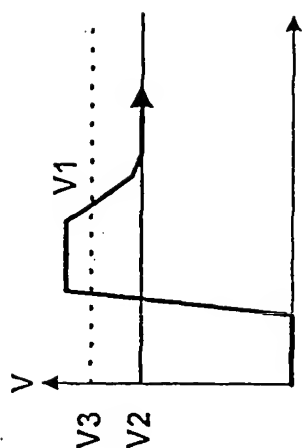
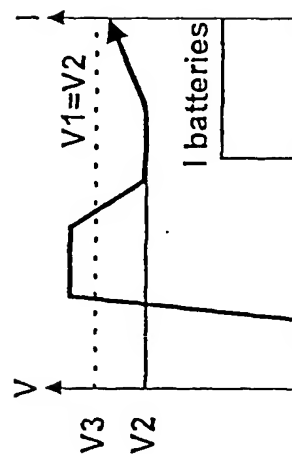


Fig. 13

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Fig. 15AFig. 15BFig. 15CFig. 14

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Fig. 15DFig. 15E



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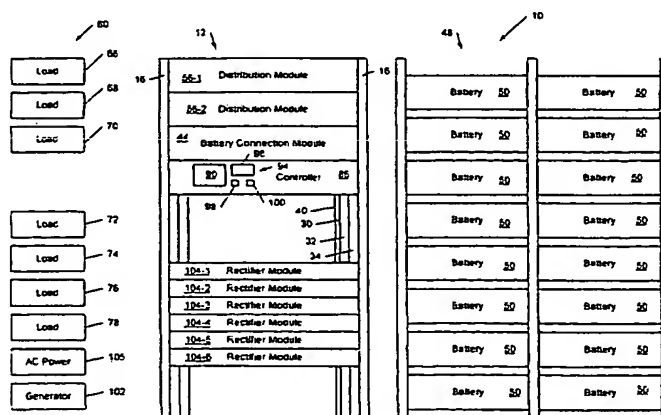
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[Continued on next page]

(54) Title: BACKUP BATTERY RECHARGE CONTROLLER AND BATTERY RECONNECT SYSTEM FOR A TELECOMMUNICATIONS POWER SYSTEM



(57) Abstract: A telecommunications power system according to the invention includes a power bus and a battery module with a plurality of batteries that are connected to the power bus. A plurality of rectifier modules is connected to the power bus and usually at least one AC power source. A generator may provide backup AC power to the rectifier modules when the AC power source is interrupted. A controller includes a battery recharging control module that allows the user to select a first mode of operation that allows the generator to recharge the battery when the generator provides the backup AC power. A second mode of operation prevents the batteries from recharging when the generator provides the backup AC power. A third mode of operation decreases current provided by the generator to charge the batteries when the generator is in an overload state until the overload state ends. A fourth mode of operation prevents battery charging when the generator is in the overload state. A controller is connected to the rectifier modules and the generator and may disconnect the batteries using the contactor when a voltage of the batteries falls below a low voltage disconnect threshold when AC power is lost and/or the rectifier modules fail.

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EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 929 538 A (O'SULLIVAN ET AL.) 27 July 1999 (1999-07-27) abstract column 12, line 34 -column 13, line 20 column 14, line 9-41 column 15, line 13-56; figures 1,6-13	1,7,13, 20,27,28
A	US 5 563 802 A (PLAHN ET AL.) 8 October 1996 (1996-10-08) abstract column 4, line 45 -column 6, line 24 column 6, line 56 -column 8, line 2; figures 1-3,6	1,7,13, 20,27,28

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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